REMARKS

This Preliminary Amendment cancels without prejudice original claims 1-14 in the underlying PCT Application No. PCT/DE03/01717 and adds new claims 15-28. The new claims conform to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(ii) and § 1.125(c), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.
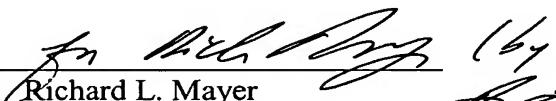
The underlying PCT Application No. PCT/DE03/01717 includes an International Search Report, dated October 15, 2003. The Search Report includes a list of documents that were uncovered in the underlying PCT Application.

Applicant asserts that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

Dated: 3/24/05

By: _____

Richard L. Mayer
(Reg. No. 22,490)

One Broadway
New York, NY 10004
(212) 425-7200

CUSTOMER NO. 26646

METHOD, CONTROL UNIT, AND COMPUTER PROGRAM FOR DETECTING DEFECTIVE PRESSURE SENSORS IN AN INTERNAL COMBUSTION ENGINE

Background Information<u>Field of the Invention</u>

The present invention relates to a method, a control unit, and
a computer program for detecting a defective intake-manifold
5 pressure sensor and/or a defective ambient-pressure sensor in
an internal combustion engine.

<u>Background Information</u>

10 An intake-manifold pressure sensor is used, for example, to
diagnose the exhaust-gas recirculation in an internal
combustion engine and therefore supplies important information
for a control unit to control the internal combustion engine.
A load signal representing the current load of the internal
15 combustion engine, or the setting of a correct torque selected
by the driver, may be derived from the pressure in the intake
manifold. In addition, an optimum injection time in an
internal combustion engine having throttle control may be
ascertained from the load signal.
20

Because of the described, high importance of the intake-
manifold pressure sensor during the operation of an internal
combustion engine, it is desirable for defects in the intake-
manifold pressure sensor to be diagnosed early.
25

Diagnostic methods for detecting the defectiveness of intake-
manifold pressure sensors are already known fromin the related
art, but only in the case of conventional gasoline engines, in
particular spark-ignition engines. The conventional internal

combustion engines are distinguished in that their load
control is implemented via the throttle valve, where there is
a fixed relationship between the pressure in the intake
manifold and the load, or between the throttle-valve angle and
5   the load.

An example of such a diagnostic method for conventional spark-
ignition engines is ~~known from~~described, e.g., in published
German patent document DE 199 46 874 ~~A1~~. Here, three different
10   signals L1, L2, and L3 are produced from different operating
parameters, L1 representing the mass flow rate of air that
flows into an intake manifold of the spark-ignition engine, L2
representing the pressure in the intake manifold, and L3
representing a fuel signal ascertained from the mass flow rate
15   of fuel. These signals are compared to each other in pairs and
united to form combinations when variations occur. Different
combinations of deviations are assigned different causes,
i.e., different sources of error, for the deviations. Thus,
e.g., in a first part of the method, it can initially be
20   deduced that, when a particular deviation is present, either
the intake-manifold pressure sensor and/or the exhaust-gas
recirculation valve is defective. In a further part of the
method, it may then be determined more accurately if the
intake-manifold pressure sensor or the exhaust valve is
25   defective. To this end, the pressure in the intake manifold
during both the operation of the engine and its stoppage is
measured and evaluated during the post-operation of the
corresponding engine control unit. If the intake-manifold
pressure is the same in both cases, it may be deduced that
30   there is a defect in the intake-manifold pressure sensor;
however, if the pressure in the intake manifold while the
engine is stopped is less than that when the engine is being
operated, it may then be deduced that an exhaust-gas
recirculation valve is defective.

In addition, ambient-pressure sensors for use in internal
combustion engines are known in the related art. In addition
to the intake-manifold pressure sensors, they also supply
5   important information for a control unit to control an
internal combustion engine. Ambient-pressure sensors are used
for, inter alia, ascertaining the maximum torque of the
internal combustion engine. Diagnostic methods for ambient-
pressure sensors are also known in the ~~related~~ art. In
10   conventional gasoline engines in which the load is controlled
via the throttle valve, an ambient-pressure sensor can,
however, only be checked for its correct method of
functioning, i.e., plausibility-checked, while starting or
during full load, since in conventional gasoline engines, a
15   pressure that approaches ambient pressure is only present in
the intake manifold under these conditions.

However, in internal combustion engines having variable valve
timing, i.e., in internal combustion engines having
20   throttleless load control, the load of the internal combustion
engine is no longer controlled via the throttle valve and,
therefore, via the pressure in the intake manifold, but rather
via a change in its valve timing and/or its valve lift. The
internal combustion engines having fully variable valve timing
25   are distinguished by a lower fuel consumption than
conventional gasoline engines.

Fig. 3 schematically illustrates such an internal combustion
engine 100 having variable valve timing. Internal combustion
30   engine 100 includes an engine block 110 having a piston 112,
which moves up and down in it. Connected to the engine block
is an intake manifold 120 having a built-in throttle valve 122
and an exhaust pipe 130. However, in contrast to conventional
spark-ignition engines, throttle valve 122 is not used for

controlling load. The control of the air supply and air exhaust through the intake manifold and the exhaust pipe, and therefore the control of the load of the internal combustion engine, is carried out via valves 140, which are controlled by

5   a control unit 200, the control being implemented with the aid of fully variable timing edges. Instead of a single control unit 200, several control units interconnected by any communication link may also be used for controlling valves 140. The valves may be moved, for example, by electromagnetic

10   or electrohydraulic actuators.

Control unit 200 includes an ambient-pressure sensor 210 for supplying a throttle-valve pressure signal, which represents pressure p_before_DK upstream from throttle valve 122. In this

15   context, ambient-pressure sensor 210 does not directly supply pressure p_before_DK, but it primarily supplies only the ambient pressure, i.e., the air pressure upstream from air filter 150 of the internal combustion engine. Then, actual pressure p_before_DK upstream from the throttle valve may be

20   subsequently derived in either ambient-pressure sensor 210 itself or control unit 200, by subtracting a pressure drop occurring in air filter 150 of the internal combustion engine from the measured ambient pressure.

25   In throttleless operation of the internal combustion engine, the pressure upstream from the throttle valve must be equal to the pressure in the intake manifold. An intake-manifold pressure sensor 220 is typically provided in the case of the control units of the related art. Intake-manifold pressure

30   sensor 220 provides an intake-manifold pressure signal, which represents pressure p_intake in intake manifold 120 of internal combustion engine 100. Sometimes, they are additionally provided with an ambient-pressure sensor 210.

However, as ~~just~~ explained <u>above</u>, since the load control in
internal combustion engines having fully variable valve timing
is no longer implemented via the throttle valve, all of the
already known diagnostic methods for pressure sensors, which
are based on deriving a load signal representing the load of
the internal combustion engine from the angular position of
the throttle valve or the pressure in the intake manifold, are
no longer applicable to internal combustion engines having
fully variable valve timing.

10

Therefore, ~~on the basis of the mentioned related art, the~~<u>an</u>
object of the present invention is to ~~further develop~~ <u>provide</u>
a ~~known~~ method, a ~~known~~ control unit, and a ~~known~~ computer
program for detecting a defective intake-manifold pressure
sensor and/or a defective ambient-pressure sensor ~~in a~~
~~conventional internal combustion engine in such a manner, that~~
~~this detection is also possible~~ in internal combustion engines
having fully variable valve timing.

20 <u>Summary</u>

This object is achieved by the method ~~claimed in Claim 1,~~
<u>control unit, and program according to the present invention.</u>
In contrast to the related art, the ~~claimed~~<u>present</u> method
dispenses with deriving load signals from the position of the
throttle valve or from the intake-manifold pressure for
detecting if at least one of two pressure sensors, namely the
intake-manifold pressure sensor or the ambient-pressure
sensor, is defective. Instead, the method of the present
invention allows this detection to take place exclusively on
the basis of a direct evaluation of the pressure upstream from
the throttle valve and the pressure in the intake manifold.

According to ~~a preferred, advantageous refinement~~ an example an example embodiment, the ~~claimed~~ method includes further steps, in order to be able to determine which of the two pressure sensors is defective. To this end, the internal combustion

5   engine having throttleless load control is artificially shifted into an operating state, which simulates throttled load control. In the scope of this simulation, it is also possible to then derive simulated load signals from both the pressure in the intake manifold and the angular position of

10   the throttle valve. According to the present invention, the simulated load signals are used for identifying the pressure sensor that is actually defective.

~~The above-mentioned object of the present invention is also~~
15   ~~achieved by the control unit claimed in Claim 6 and the~~
~~computer program claimed in Claim 13.~~

~~The advantages of the control unit and the computer program~~
~~essentially correspond to the above-mentioned advantages with~~
20   ~~regard to the claimed method.~~

~~Further advantageous refinements of the claimed method, the~~
~~control unit, and the computer program are subject matter of~~
~~the dependent claims.~~

25
~~Preferred exemplary embodiments of the present invention are~~
~~subsequently explained in detail in light of the attached~~
~~figures. The figures show:~~ Brief Description of the Drawings

30   Fig. 1a shows an example embodiment of a method of the present invention for detecting defective pressure sensors in an internal combustion engine and a first logic module provided for implementing the method~~.~~.

Fig. 1b shows an example embodiment of a control unit of the
present invention~.~

Fig. 2 shows another example embodiment ~A further refinement~
of the method according to the present invention and a second
logic module provided for implementing the further refinement~,~
~and~.

Fig. 3 shows a ~known~ conventional internal combustion engine
having variable valve timing, and a corresponding,
~known~conventional control unit for controlling the valves.

Detailed Description

Fig. 1a illustrates a method for determining whether or not at
least one of two pressure sensors, namely the intake-manifold
pressure sensor and/or the ambient-pressure sensor_, is
defective in the case of an internal combustion engine having
variable valve timing ~in accordance with~ as shown in Fig. 3.
The method steps ~according to~ illustrated in Fig. 1a ~does~do
not ~yet~ allow one to specifically determine which of the two
pressure sensors is defective; such a determination may ~only~
be made with the aid of ~the~ further ~refinement~steps of the
method described below with reference to Fig. 2.

The method is illustrated in Fig. 1a by showing the functional
layout of a first logic module 240 according to the present
invention, which ~is preferably~may be a component of a control
unit 200 for controlling the valves of internal combustion
engine 100, ~see~which control unit 200 is shown in Fig. 1b.
First logic module 240 allows the claimed method to be
implemented. The layout of first logic module 240 is described

below in detail; the individual steps of the claimed method ~~are~~may also ~~automatically~~be deduced from this.

According to Fig. 1a, first logic module 240 receives both a
throttle-valve pressure signal, which represents pressure
p_before_DK, and an intake-manifold pressure signal, which
represents pressure p_intake in the intake manifold of the
internal combustion engine~~, in order to generate~~. Generation
of these signals~~: see~~ is described below in connection with
Fig. 3 ~~and the corresponding part of the description~~.
According to the present invention, first logic module 240
also receives a first status signal from a first operating-
state detector 230, the first status signal indicating whether
or not the internal combustion engine is being operated in a
throttleless operating state. As an alternative, the status
signal may also be generated by another logic module inside
control unit 200.

As shown in Fig. 1a, logic module 240 includes a first
subtraction unit 242 for calculating a pressure difference
delta_p by subtraction of the intake-manifold pressure signal
from the throttle-valve pressure signal. This pressure
difference is supplied to a first comparator unit 244, which
determines if pressure difference delta_p is greater than a
first threshold value Delta_P1. A first AND gate 246 ANDs the
logical output signal of first comparator unit 244 and the
first status signal. The output signal of this first AND gate
246 makes a first statement as to whether or not one of
pressure sensors 210, 220 is defective; this is exactly the
case, when pressure difference delta_p is actually greater
than first threshold value Delta_P1 and internal combustion
engine 100 is simultaneously being operated in a throttleless
manner, as indicated by the first status signal. In this

context, first threshold value Delta_P1 ~~is preferably~~may be set to approximately zero.

includes a second comparator unit 248 for determining if
5   pressure difference delta_p is less than second threshold value Delta_P2, where Delta_P2 ~~is preferably~~may be zero. When this is the case, then, independently of the first statement, it is possible to make a second statement that one of the two pressure sensors 210, 220 is operating incorrectly. This
10   statement is physically based on the fact that the pressure in intake manifold 120 can never be greater than the pressure upstream from throttle valve 122.

First logic module 240 also includes an OR gate 249 for ORing
15   the output signal of first AND gate 246 and the output signal of second comparator unit 248. This OR operation is used for generating a first error signal E_DS_DSU, which represents an error in one of the two pressure sensors 210, 220, when such an error has already been detected at either the output of
20   first AND gate 246 or at the output of second comparator unit 248 or at both outputs.

Fig. 2 illustrates another example embodiment, which is a further refinement of the method represented in Fig. 1, this
25   further refinement being used to allow an exact determination as to whether the intake-manifold pressure sensor or ambient-pressure sensor 210 is defective. This further refinement is implemented in the form of a second logic module 250, which ~~is preferably~~may be assigned to control unit 200 as well, ~~see~~as
30   shown in Fig. 1b.

According to Figures 1b and 2, second logic module 250 implements the above-mentioned further refinement of the method by logically combining first error signal ES_DS_DSU, a

first load signal load_from_intake-manifold-pressure, which represents the load of the internal combustion engine derived from the pressure in the intake manifold, and a second load signal load_from_DK, which represents the load of the internal

5   combustion engine derived from the angular position of throttle valve 122.

To implement the further refinement of the method, an operating state that includes throttled load control is

10   simulated in the internal combustion engine 100 having absolutely variable valve timing. To this end, valves 140 are preferably controlled by control unit 200, using fixed timing edges. This special operating state is represented by a second status signal B_DK_occurred, which is likewise supplied to

15   second logic module 250 as an input variable.

Second logic module 250 includes a second subtraction unit 251 for calculating a load difference by subtraction of the second load signal from the first load signal, as shown in Fig. 2. An

20   absolute-value generator 252 calculates the absolute value of the load difference before this is supplied to a third comparator unit 253. Third comparator unit 253 determines if the absolute value of the load difference is greater than a third threshold value Delta_load.

25

A second AND gate 254 ANDs first error signal E_DS_DSU and second status signal B_DK_occurred. The output signal of second AND gate 254 is transmitted, together with the output signal of third comparator unit 253, to a third AND gate 255,

30   which means that the output signal of third AND gate 255 represents the result of ANDing the mentioned, inputted signals. In other words: the output signal of third AND gate 255 represents a second error signal E_DS_intake, i.e., it indicates, if applicable, the defectiveness of intake-manifold

pressure sensor 220. Such defectiveness is present, when the
absolute value of the difference of the load of the internal
combustion engine derived from the pressure in the intake
manifold and the load derived from the angle of the throttle
5   valve is greater than third threshold value delta_load, and
when, in addition, the presence of a defect in at least one of
the pressure sensors, ambient-pressure sensor 210 or intake-
manifold pressure sensor 220, was simultaneously detected in
the preliminary procedure described above with reference to
10   Fig. 1a, and when an operation that includes throttled load
control was simulated in internal combustion engine 100. The
conclusion that the intake-manifold pressure sensor is
defective is valid, since signal load_from_DK is reliably
monitored by other diagnoses and is therefore correct.
15

Second logic module 250 further includes a fourth AND gate 256
for ANDing the output signal of comparator unit 253 inverted
by an inverter 257 and the output signal of second AND gate
254, as shown in Fig. 2. The output signal of fourth AND gate
20   256 represents a third error signal E_DS_Umg, which indicates,
if applicable, a defect in ambient-pressure sensor 210. Such a
defect is present, when the absolute value of the difference
of the load of the internal combustion engine derived from the
pressure in the intake manifold and the load derived from the
25   angular position of the throttle valve is less than or equal
to third threshold value Delta_load, and, at the same time, a
defect in at least one of pressure sensors 210, 220 was
already absolutely detected in the preliminary procedure
described above with reference to Fig. 1, and an operation
30   that includes throttled load control was simulated in the
internal combustion engine.

Both the first and second logic modules may each be implemented independently of each other in the form of a hardware circuit.

5   ~~However, it is particularly important to implement the~~The method of the present invention, and therefore ~~to implement~~also the first and/or second logic module 240, 250, may be implemented in the form of a computer program. In this context, the computer program is executable on a computing

10   element, ~~particularly~~e.g., on a microprocessor in control unit 200, and is suitable for carrying out the method of the present invention. In this case, the present invention is therefore implemented by the computer program~~, so that this computer program represents the present invention in the same~~

15   ~~manner as the method, for whose execution the computer program is suitable~~. The computer program ~~is preferably~~may be stored in a memory element. In particular, an electrical storage medium, e.g., a random-access memory (RAM), a read-only memory (ROM), or a flash memory, may be used as the memory element.

20

~~Abstract~~ <u>ABSTRACT</u>

~~The invention relates to a~~<u>A</u> method, <u>a control</u> unit ~~200~~, and <u>a</u> computer program for detecting a defective intake-manifold pressure sensor ~~220~~ and/or a defective ambient-pressure sensor ~~210~~ in an internal combustion engine ~~100. The related art already describes diagnostic methods and devices for detecting the defectiveness of intake-manifold pressure sensors, but only in conventional internal combustion engines in which the load is controlled via the throttle valve 122, and not for internal combustion engines 100 in which the load is controlled via the valve timing. Therefore, on the basis of this related art, the object of the present invention is to further develop a known method, a known control unit 200, and a known computer program for detecting a defective intake-manifold pressure sensor 220 and/or a defective ambient-pressure sensor 210 in a conventional internal combustion engine 100 in such a manner, that this detection is also possible in internal combustion engines 100~~ having <u>a variable</u> valve timing <u>are provided</u>. ~~This object of the present invention is achieved in that the~~<u>The</u> desired detection is carried out exclusively on the basis of a direct evaluation of the pressure upstream from the throttle valve ~~122~~ and the pressure in the intake manifold ~~120~~. This ~~advantageously~~<u>method</u> eliminates the need for deriving load signals from these pressures, ~~as is necessary in the related art,~~ at least for the determination as to whether at least one of the pressure sensors is defective ~~(Fig 1)~~.